

FAST REGION DESCRIPTION METHOD FOR CONTENT BASED MEDICAL IMAGE RETRIEVAL

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Abstract - A new approach to segmented image representation and description for content-based medical image searching is proposed. Using the method a table of image runs is dynamically constructed. The table is used by a grouping process running on the oversegmented image to reduce small regions. In the framework of the content-based querying the table is also applied to describe regions and their contours (inner borders). The shape descriptors like an area, a perimeter and a compactness are used to indicate basic region properties. Application of the method for CT and MRI images produce good results, which are presented and discussed in this paper.

Keywords - Region detection, RLE, content based retrieval

I. INTRODUCTION

With the rapid advances in multimodal medical imaging and PACS systems, it is increasingly important to retrieve images from medical databases by visual features either locally or over computer networks. Content-Based medical Image Query (CBIQ) system can be very useful to assess the quality of diagnosis. It can also be used as an intelligent medical assistant, or can act as a support tool, in a pure information browser, for guiding a search by content in electronic medical image archives. For the *search by content functionality*, the definition of appropriate features and their syntactic description, as envisaged in MPEG7, is of primary importance. Medical applications require to investigate regions of an image rather than the entire image. Region detection and description methods play a very important role for a Content-Based medical Region Query (CBRQ) system. In this paper a new approach to segmented image representation and description for content-based medical image searching is proposed.

II. RELATED STUDIES

Thresholding is the simplest, fast yet often effective, segmentation method [1]. In content based searching the most important is to indicate the presence of region presence in the image, not it's very accurate borders, which can be identified latter using more precise segmentation or region detection algorithms. Different thresholding methods has been proposed. The simplest method divides the histogram domain into equal N compartments. Another methods are looking for peaks and valleys, which are used to set thresholds. Interesting modification of peak and valleys method is the triangle algorithm proposed in [2]. Other method is based on modified image histogram created as a result of edge detection [1]. Some optimal thresholding methods has been also proposed. These methods rely on maximization (minimization) of a merit function. Some examples are those using clustering operations [3][4] or

those based on a model [1]. However most of them uses statistical measures (e.g. variance) to perform tests on threshold selection. Those statistical indicators are calculated for each possible threshold location, so it is a time consumed procedure. In this paper, the shape-based histogram technique is proposed and used.

If a region border is not known but segments have been defined in the image, borders can be uniquely detected. A very efficient method for tracking region contour are "snakes" [5]. Active contours are dynamically modified by minimizing their energy. "Snakes" are successfully applied to singular regions within an image, e.g. a tumor area, but not for the complete set of regions composing the image. Another, well defined method for a contour tracking and description is the chain coding or Freeman coding [6]. In this method the contour is followed from a starting point by encoding each pixel location in terms of the relative direction from its neighbor. The Freeman chain codes is a compact way to represent a contour of a region, since only a starting point coordinates and a set of simple (3 bits) direction codes are stored. The contour compression can be even better with proposed in [7] improvements of chain cods schemes. However chain code has drawbacks when used for content based retrieval. It must be additionally processed to decode absolute region border, and to calculate a region descriptors. Other methods for a contour representation are often constructed as graphs [8]. Graphs provide access to the local topological structure of the image, but the shape of the object is only available with additional examination.

In content-based region querying system proposed in [9] the binary matrix is used to represent only part of an image, for which feature data are computed. The disadvantage of this method is requirement of unuseful background data storage and additional calculations of region pixel coordinates.

III. METHODOLOGY

Before regions existing in an image are described they must be detected. First a fast thresholding method can be used as a segmentation method. A pre-filtering algorithm is applied to an image to eliminate separate pixels. Let's define the $N8$ as 8-connectivity neighborhood of the processed pixel $P(x,y)$, $\min N8$ as a minimal value in $N8$, $\max N8$ as a maximal value in $N8$ and $wN9$ as a vector of all pixel values in $N8$ and processed pixel value. The pre-filtering operator modifies the pixel $P(x,y)$ value according to the schema

```
TEST = mediana(wN9)-P(x,y);
If ( P(x,y)<minN8 )
    T=K * minN8;
    max=false;
```

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If ( P(x,y)>maxN8 )
  T=maxN8 / K;
  max=true;
If ( |TEST| > T )
  If ( max )
    P(x,y)=maxN8;
  Else
    P(x,y)=minN8;

```

where K is the scaling factor of the decision threshold. In most cases of CT and MRI images used in reported experiments $K = 1..3$.

Pre-filtered image is suitable for thresholding. The modified histogram “peak and valley” method is used for segmentation. The histograms of CT or MRI images have usually two separate groups of values, the foreground group which corresponds to pixels reconstructed for the measured object (human body) and the background group which consists of pixels calculated for the object outer space (air). Example of MRI image histogram is presented in figure 1. Values of an image belonging to the foreground group represent different tissues and are very often spread around of a one value composing small compartments in histograms. This feature is frequently used to compose the image presentation context (e.g., a window center and width). However in the original CT and MRI image histograms local fluctuations are observed. In our studies a morphological opening operator is applied to a histogram.

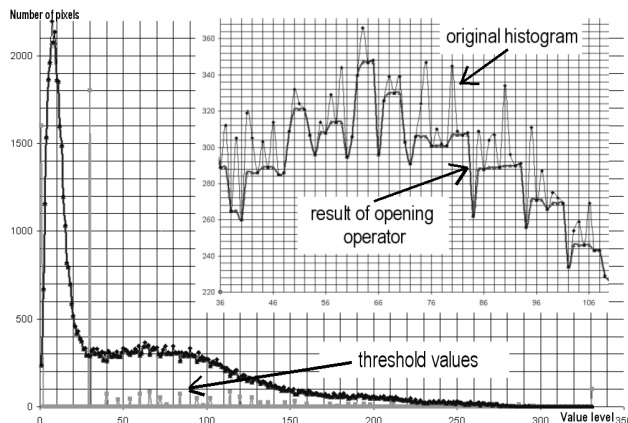


Fig. 1. Examples of MRI image histogram with indicated result of morphological opening operator.

After elimination of small fluctuations from a histogram its local minimal values are detected and used for thresholding. As a result a set of threshold values are produced whose total number is usually less than 30 (tested on 1320 T1 and T2 weighted MRI images and 1560 CT images). The number of thresholds can be controlled by sequential elimination of these thresholds with the smallest “peaks to valley” gradients. Each threshold produces a set of non-adjacent regions of pixels resulting in a high number of image segments. The oversegmented image requires additional processing to merge those of regions which are most similar to each other or those which area is smaller than a given value. This can be achieved by analyzing such particular region properties like a mean value, a location,

neighborhood, an area, other properties. Additionally, in the framework of the content based retrieval, a region description method should be fast and produce a compact representation of a region, suitable to store it in a descriptors database.

The first task in the proposed method of region contour detection and description is generation of an image run-length codes (RLC). With a one pass scanning of an image a table consisting of N (N - number of runs) runs is constructed. Each row of the table stores four run attributes: a value of the run V, the first pixel of the run FP (From Pixel), the last pixel of the run TP (To Pixel), and the region label which run belongs to. Additionally indexes of first occurrences of runs in a each image raw are stored in a temporary vector. Region labels are constructed dynamically according to newly connected runs. The region labeling algorithm operates as follows:

1. label all runs of the first raw,
2. store temporarily the first and the last RLC table indexes of all runs for the first image raw,
3. move before the first run of the next image raw,
4. take the next run,
5. test if the current run is adjacent to a any from the previous image raw with a given value,
6. if “yes”, add its label to a Temporary Label Vector TLV,
7. if all previous runs are tested assign the smallest label value to the current run and to all cells of the external vector S addressed by the labels stored in the TLV; clear TLV,
8. if “no”, assign a new label to the current run,
9. store temporarily the first and the last RLC table indexes of all runs for the current image raw,
10. if there are more unprocessed runs go to 3 else stop.

At the end additional single pass re-indexing of region label list must be done basing external vector S. The algorithm requires only the previous image raw runs to test for adjacency so it operates fast. Similar method of region synthesis was introduced in [10], with application of dynamically created region objects instead of labeling.

The result of region synthesis from the RLC table gives a set of regions defined by runs. With such representation it is possible to efficiently calculate the total area of the region as

$$A = \sum_{i=1}^R (TP_i - FP_i + 1), \quad (1)$$

where R – number of runs belonging to the current region.

Having the region area, the region value and its location only its neighborhood information is additionally required to start region merging operation. Region neighborhood can be evaluated using the property of the constructed RLC table. Since each run is stored as a new raw, it is very easy to seek all runs that are previous or next to runs belonging to the processed region. In this way all horizontal neighbors can be detected and ordered according to values similarity and the total number of common border pixels. Since RLC table generation requires only 3M (M – number of an image pixels) integer operations (comparisons and additions only),

it can be repeated for columns of image matrix. Vertical runs are labeled into regions based on comparisons with RLC table of horizontal runs (equal values of V and FP for horizontal and vertical runs). Having the RLC table of vertical runs their nearest neighbors can be detected. In this way all horizontal and vertical regions next to the processed region are extracted and described by the total number of neighbor pixels and corresponding values. Now it is possible to define regions merging algorithm as

- A. for each region i next to the processed region
 1. calculate gradient of corresponding values

$$grad = V - reg[i][0], \quad (2)$$

where V is the processed region value, $reg[i][0]$ is the value of the i -th neighbor region;

2. if the absolute value of the gradient is lower than or equal to the threshold value Tp ; calculate new gradient value as

$$nV = \frac{P \cdot grad}{reg[i][1]}, \quad (3)$$

where P is the processed region perimeter, $reg[i][1]$ is the common border of the processed and i -th neighbor region;

3. if nV is lower than current minimal value set it as minimal value and store the neighbor region index $ind=i$

B. if processed region area is lower than an arbitrary set region area Ap or if minimal nV is lower than an arbitrary set threshold value Vt join current region and the region identified by $reg[ind][2]$, where $reg[ind][2]$ is the label of the ind -th neighbor region.

Because of its parameters the algorithm is universal, however in our studies we merged only those regions which were smaller than 16 pixels ($Tp=0$, $Ap=16$, $Vt=0$). Required perimeter value is the total sum of all pixels belonging to the inner border of the region (external and internal contours). Let's assign a value "1" to all pixels, members of the processed region and a value "0" to the rest of pixels. In our studies perimeter can be defined as the total number of pixels with value "1" after application of the following formula to the image I

$$Ip = I - E(I, N4), \quad (4)$$

where $N4$ is the 4-connectivity structure element and $E(I, N4)$ is the morphological erosion operator.

This definition is equivalent to the total number (without repetitions) of FP and TP positions of horizontal and vertical runs of the processed region. In this way the next region descriptor (perimeter) can be effectively calculated. The last region descriptor used for content based region retrieval system is the compactness. It is defined as

$$C = \frac{P^2}{A}. \quad (5)$$

The compactness is optimal for a circle. It is possible to calculate the compactness "in the fly" based on the stored perimeter and area or pre-compute it and store as additional region parameter.

The final task of the region description for content based region searching system is definition of such a region representation, that it is compact and enables fast

identification of the region in the image it belongs to. The best method is to represent and store region borders. It can be easily done since the collections (without repetitions) of FP and TP coordinates of vertical and horizontal runs compose the inner border of the region. The simple rearrangement of this collection enable to represent region borders using a sequence of column identifiers of the border pixels listed from the first to the last region row. The region representation algorithm based on RLC tables can be described as

1. for each row store all run elements which belong to the border;
2. if within a one row two or more separate runs of the region exist store the value "-1" between the last and the first coordinates of corresponding border elements of runs,
3. if the first column coordinate of the next row run is greater than the last column coordinate of the current row run store the "-2" value before the next row run.

This results with the set of border pixels coordinates related to columns. Additionally the identifier of the first region row has to be stored. Together with the value of the region the full description of the region is created. The simple example of the region description is presented in figure 2. Description can be

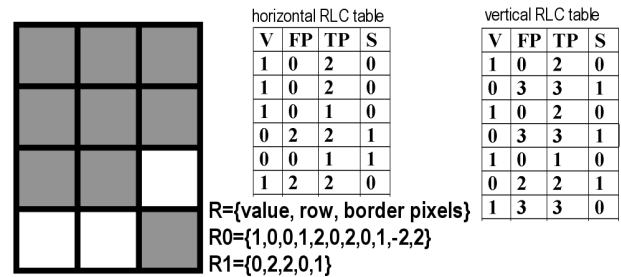


Fig. 2. Example of region description result

stored as rows in tables (e.g., in a relational database) or as persistent objects (in an object oriented database). It is also possible to add additional fields to a region row or an object to store descriptor values like area, perimeter, compactness, etc. In this case the example of region description class in object oriented design is

```
class Region{
    int value;
    int area;
    int perimeter;
    int compactness;
    int first_row;
    int border[];
}
```

However the interesting feature of the proposed region description is that descriptor values can be calculated "in the fly" based on the introduced region representation. Simple, perimeter is the total number of all positive values representing the region border. The area is equal to the perimeter extended with all pixels between runs, stored in the

border description (in the presented example of R0, the 0,2 gives additional pixel of 1 to the area).

III. RESULTS AND CONCLUSION

The presented method of region description for content based searching system was verified using simple test images and real medical images (1320 T1 and T2 weighted MRI images and 1560 CT images). Medical images were stored in primary captured DICOM format, so the original representation of data was used (usually 12 bits). Particular algorithms were implemented in Java programming language using Sun JDK 1.2. Running the application on different platforms very fast results of the described method were produced. Since specification of time depends on platform configuration, it is more useful to calculate the number of operations. In the proposed method the total cost of operations can be calculated as

1. RLC tables generation costs: $3M+M=4M$,
2. region extraction from RLC table: $5N$,
3. region description generation: $5N$,

which gives the total number of $4M$ (M – number of image pixels) + $10N$ (N -number of runs) operations. Since most of them are scanning operations ($2M+4N$), and all of them are simple comparisons and additions of integer numbers, the method works very efficiently. In the presented cost estimation additional assumption was made that the number of runs in the horizontal RLC table is equal to the number of runs in the vertical table.

In figure 3 the test image presented in [10] and the result of its processing are presented. According to 8-connectivity test used in our method there are 4 different regions in the test image. The “foreground” region indicated with gray has external and internal borders. However for content based searching system it is useful to work with combined borders (a perimeter defined above), which represent the region. With this assumption presented method does not require any time consumed “walking” operation so it works faster.

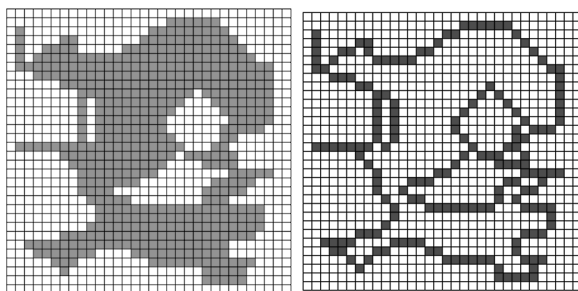


Fig. 3. Example of an inner border extraction result

In figure 4 the image from the created medical image database is presented together with the effect of thresholding and with the region generated from its description.

The proposed method can be effectively used for content based region retrieval system in different ways. First, it is

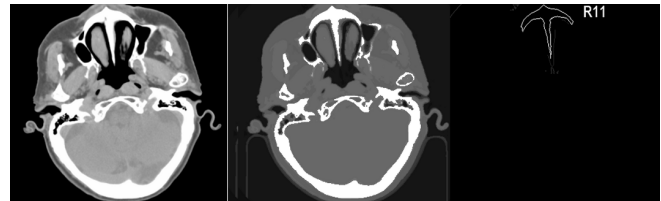


Fig. 4. Example of region description result. From left: CT image scaled to its full range, image after thresholding, a one region generated from its description.

possible to generate shape descriptors used in comparison tests; second, region location can be encoded used to a region identification in the retrieved image. Additional advantage of the method is the possibility of a region extraction from the segmented image or from the image generated as a result of pattern matching. It can be used then to generate a database of regions for particular image databases or for a collection of templates used in pattern matching.

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